# EFFECT OF MACROPHYTES ON EUTROPHIC CENTENNIAL PARK WATER NUTRIENTS

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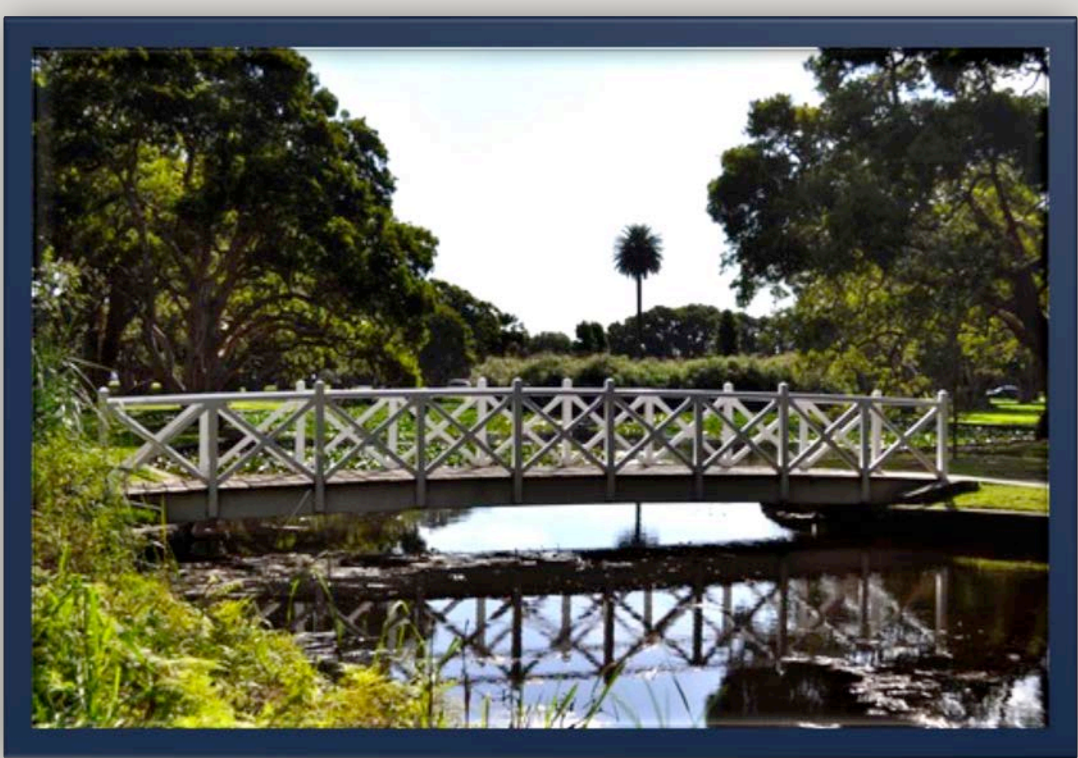


# ***Abstract***

This project aims to determine a cost effective, efficient purifying scheme to treat eutrophication, a severe type of water pollution in many water bodies worldwide. A natural macrophyte was trialed on controlling a eutrophic water source, to determine the degree of impact it had, while also establishing the best application for its success. The natural macrophyte chosen was duckweed, an aquatic plant, due to past scientific research stating its potential for eutrophication treatment. The duckweed was applied to Lily Pond water samples, a natural water source with eutrophication history. Over the investigation period, water parameters were measured using different water analysis methods. The results collected enabled a clear view on duckweed's effectiveness. To determine the best practical application course, each of the Lily Pond water samples contained a different duckweed density. The comparison of the duckweed's proficiency in different ratios enabled formulation of a practical filtering scheme. The experimental results were exceedingly promising, with duckweed removing up to 92% of harmful nitrate quantities, the main eutrophication cause. Furthermore, duckweed did not negatively impact the pH or alkalinity levels that are crucial to a healthy ecosystem. A duckweed density of 20% carried success, and a 10-day filtering scheme is proposed at the end of this report. This report details the procedures taken for nutrient data gathering, the analysis that determined the result inferences, conclusions, future improvements and practical applications.

Above: Lily Pond

## *Background*

The Lily Pond, located in Centennial Park Sydney is important habitats of a number of waterfowl (swamp hens, black swans and the reed warbler), invertebrates (dragonfly nymphs, water boatmen and aquatic earthworms). It is also a breeding ground for many species of fish (Centennial Parklands Trust). Therefore it is vitally important to monitor the water quality, especially the water nutrient levels to certify the habitat's continued quality [5].

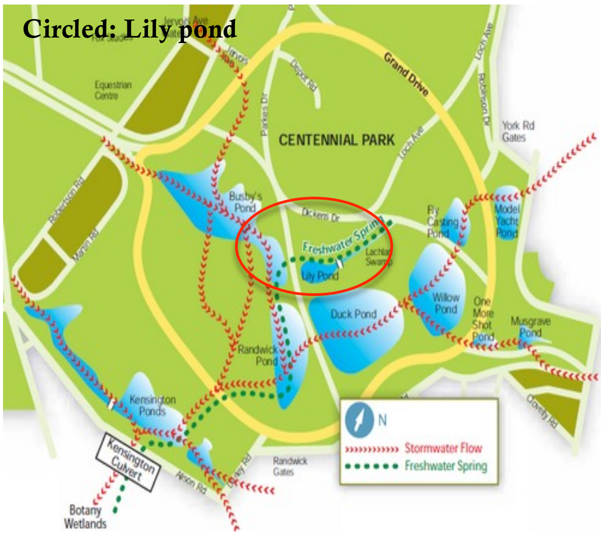
### Eutrophication

Eutrophication is an aquatic's ecosystem's response to the excess addition of artificial or natural nutrients. These excess nutrients tend to be nitrogen and phosphates, which enter the water body through fertilizers such as faeces or runoff (Encyclopedia of earth) [10]. Eutrophication can have a variety of negative effects. In freshwaters, it can lead to surface algae blooms of nitrogen-fixing cyanobacteria (known as blue-green algae) (Schindler DW, 1977) [21]. These blooms contain compounds more toxic than cobra venom (Skulberg et al., 1984) and can trigger a reduction of dissolved oxygen and in severe cases, cause marine life suffocation.

Eutrophication treatments tend to frequently utilize chemicals or microorganisms such as the usage of periphyton, a specialized bacteria colony that consumes excess nutrients [8]. However, the effectiveness of the above stated treatments are strongly inhibited by uncontrollable factors such as low light availability. (V.H Smith et al, 1998) [27] These treatment schemes also tend to be expensive and require heavy monitoring, making them not possible for large-scale eutrophication schemes, especially in rural areas or 3rd world nations (China Water Risk) [10].

### Lily Pond water pollution

In the past, lakes in Centennial Park have been affected by eutrophication on numerous occasions, particularly in the early to mid 1990's, where blue-green algae blooms were apparent in many of the Park's lakes, including Lily Pond. There was a major reoccurrence in May-August 2000 (Moore Park Trust)[6]. In 2010, the levels became acceptable but there is an elevated chance of an eutrophication reoccurrence. The cause of eutrophication in Lily Pond can be traced to the large numbers of aquatic birds in the area, for the faeces these birds produce contain high levels of nitrate, which consequently manufactures




Circled: Lily pond

eutrophication. Also, uncontrollable environmental factors in Lily Pond such as turbidity, suspended silt and the shallow pond depth favor the development of eutrophic algal blooms.

The Moore Park Trust has been especially concerned about the issue of eutrophication and it's affect on the wide ecosystem in the pond. The Trust installed Gross Pollutant traps, installed at runoff entry points, to help filter out dissolved pollutions such as phosphorus, one key cause of eutrophication. They have also started to undertake regular water quality analysis, to monitor pond health. These treatment programs are quite expensive, with the total cost of pond rehabilitations for Lily Pond and it's surrounding water sources in 2012-2014 being 1.8 million. However, though these treatment programs are proving to help filter the water quality, to prevent eutrophication occurring once again, a larger scale operation needs to be conducted, with the possibility of an aquatic plant filtering system being explored by the trust (Lily Pond treatment programs) [17].

**Duckweed applications**

Duckweed (*Lemna sp.*) is renowned for it's bioremediation advantages. Harvesting duckweed can help remove surplus nutrients, which might otherwise be released into aquatic environments through natural runoffs or wastewater plants (Smart et al, 1984)[23] It is particularly proficient at removing harmful levels of nitrate, ammonium and phosphate. In a research paper by the *Swiss Department of Water and Sanitation in Developing Countries,* the SDWSDC stated that duckweed has great potential for algae growth control. In an independent study by the N.C Museum of Natural Sciences, it was stated that over the course of 4 weeks in a 25cm by 25cm area pond that was 9cm in depth, a small sample of duckweed was proven to eliminate all traces of nitrogen and phosphate from the water. (SANDEC) [20]

Duckweed is also presented as a valuable food source for fish, birds, or other aquatic creatures, having been promoted for use by the Word Bank, especially in third world countries (Skillicorn et al., 1993) [22]. This is due to it having a stronger array of essential amino acids than regular vegetable proteins (Hillman and Culley, 1978) [15]

## ***Aim***

The first aim of this study is to determine whether duckweed would be suitable for eutrophication prevention or control. The second aim is to then determine the best density of duckweed to water area for optimum absorption that decreases excess harmful nutrients while not stripping essential nutrients for a healthy ecosystem.

## ***Hypothesis and Prediction***

HYPOTHESIS- Duckweed will be a strong filtering scheme for excess nutrients and the optimum ratio will be a 25% plant to water ratio
PREDICTION- Duckweed's effectiveness is based on past research showing potential for it to control eutrophication. In terms of the optimum density, it is assumed that a 20% density will not be strong enough a filter to remove excess water nutrients while a 33% or 50% duckweed density may strip essential water nutrients and affect on a stable ecosystem.

## ***Risk Assessment***

Risks associated with my project are:

- **Chemical Storage**- Many of the chemicals used were flammable and harmful. To ensure no accidents, chemicals were placed on a high shelf in basement far from combustible materials, flames or unwary persons.
- **Chemical Use**- While handling the compounds, disposable gloves and a pair of goggles were required to ensure no harmful materials enter body system.
- **Chemical Disposal-** Chemicals are required to be disposed into sink or water system away from human eating activity to avoid food or drinking contamination. In this case, all remaining substances were released into the backyard garden toilet.

## ***Materials:***

- Lake water: 25 L water was collected from Lily Pond, located in Centennial Park Sydney in March, 2015.
- Duckweed: The macrophytes Lemna sp. was obtained from Sinclair Knight Merz, and was originally isolated from a pond at Macquarie University Sydney (approx. covering of 500 $cm^2$).

### ***Other Equipment***

- Disposable Globes
- 25 L water storage container
- 9 clean water tubs of 2 L capacity
- Approx. 50x 50mL test tubes
- Ammonium Test kits
- pH meter
- Total Alkalinity test kit
- Hardness test kit
- Water colour test kit
- Iron test kit
- Phosphate test kit
- Nitrate test kit
- 2x10 mL springe
- 2x 1 mL springe
- De-ionized water

- Tissue paper
- Open storage boxes
- 2 Buckets

## *Variables*

**Controlled Variable:** amount (1.5 L) and source (Lily Pond- Centennial Park) of water, the species of plant *(Lemna sp.)* and the time period (2, 4, 6, 8, 10 days) when the measurements are taken
**Independent Variable:** Different densities of duckweed to water surface area (20%, 25%, 33%, 50%, 0)
**Dependent Variable-** The quantity of different nutrients after each time period. The nitrate, nitrite, hardness, total alkalinity and iron levels will all be measured in mg/L. The colour of water is measured in PCU, while pH is measured in pH.

## *Procedure*

1. Collect 25 L of water from the Lily Pond, in Centennial Park, in a 25 L water storage container.
2. Place 1.5 L of collected water in a 2 L capacity clean container.
3. Repeat 9 times to ensure 9 equal tub containers containing 1.5 L lake water.
4. Place tubs under clear covering, to ensure that all receive same amount of sunlight while away from external factors such as rain
5. Gather approximately 500 $cm^2$ of duckweed (Lemna sp.) from a reliable source.
6. Cover 20% of the surface area of two water containers with duckweed.
7. Repeat again with the 6 other containers but with 25%, 33% and 50% surface coverings. There should be 8 containers with 2 containers of each ratio amount and one with no duckweed as the control base for the nutrient levels.
8. Collect 100 mL of water per container every 2 days, storing in test tubes labeling the date collected and the density it was collected from
9. Refill the amount taken per container after each sample taking also adding 10 ml to combat evaporation.
10. Conduct tests for levels of:

- Hardness
- Iron
- Nitrate
- Nitrite
- pH
- Total Alkalinity
- Apparent Water Colour

## *Results and Discussion*

*After measuring water nutrient qualities every 2 days over the course of 14 days, the results have been collated and are presented below.*

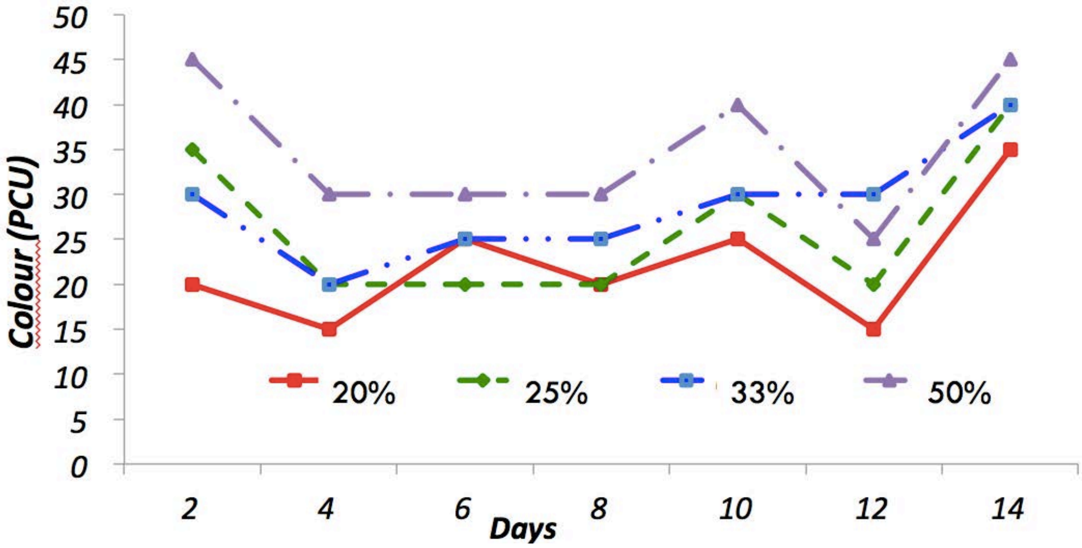



**Figure 1. Apparent colour of water in different *Lemna sp.* ratios, Initial: 15 PCU**

Figure 1 shows that the colour initial rose from 15PCU, then gradually decreased and increased again (in 20% ratio lowering from 20 to 15, rising up to 25, lowering back to 14 and rising up to 35 PCU) This is quite a high end colour measurement and shows that the ending result would have not allowed a large amount of light to pass, therefore restricting plant growth at the pond bottom.

Factors that influence apparent watercolor are the presence or absence of dead aquatic plant matter and the depth of the lake, with a lower pond depth having a higher chance of having waste matter floating. (IFAS Lakewatch) [16] In this experiment's case, the water contained both decayed aquatic plant matter from the duckweed and the depth of pond was fairly low, around 15 cm, with the plant roots being able to reach up to 5 cm below the surface. Therefore, this would have influenced the results, as there would be a higher percentage of plant matter measured in certain samples. Therefore, the lower densities (eg 20%) had a much lower PCU than the higher density, the cause of this being deduced to the 20% densities having the smallest ratio of duckweed able to enter the water sample.

From the results above, it can be concluded that a 20% duckweed surface covering would be optimum, as it had the lowest PCU, therefore allowing the most amount of light to reach the bottom of the pond and consequently, ensure the further growth of aquatic plants.

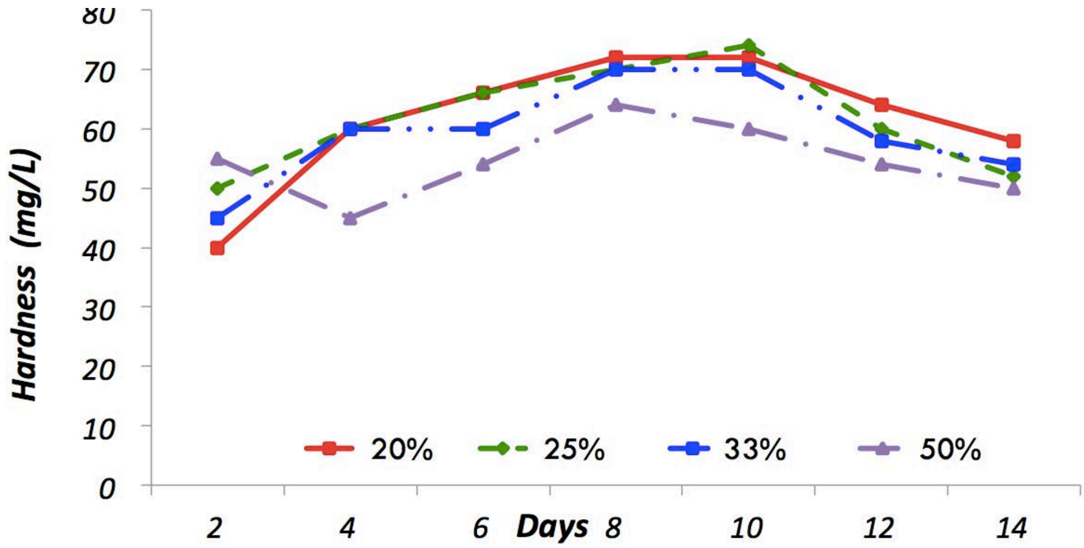



**Figure 2. Hardness of water in different *Lemna sp.* ratios, initial: 60 mg/L**
Water hardness measures the dissolved natural minerals amount, and is measured as the equivalent concentration of calcium carbonate. In Figure 2, all results are classified by the US Geological Survey as moderately hard in quality (between 75-150 mg/L). This is an acceptable outcome for fish health as extremely soft water (below 75mg/L) or extremely hard water (above 300mg/L) can affect the health of fish lungs (SASTA)[24]. Since there is not a major difference between results (with results only differing a maximum of 15 mg/L), it would be optimum to use the 20% for cost effectiveness and space for future growth.

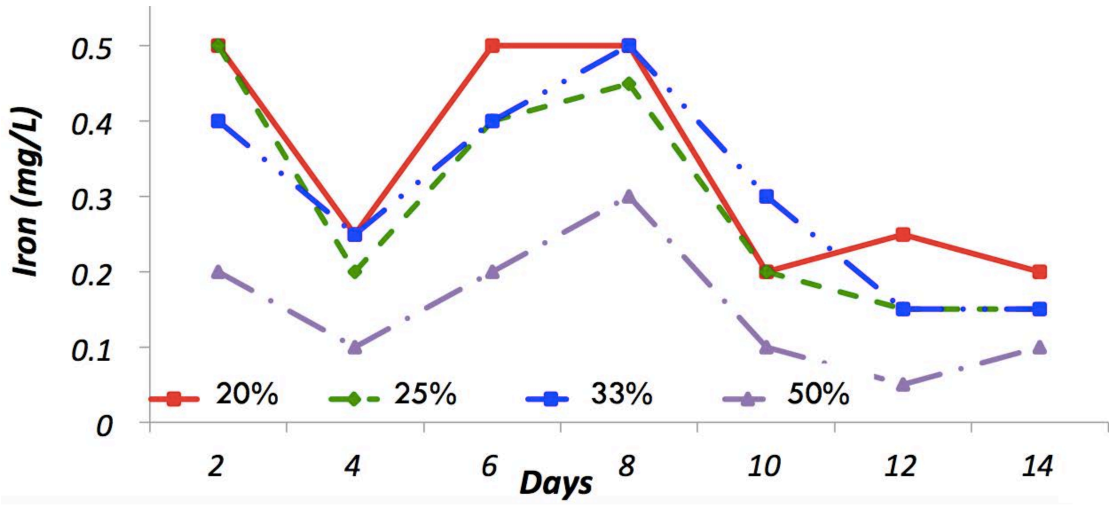



**Figure 3. Iron in different Lemna sp. ratios, initial: 0.3 mg/L**
The results in Figure 3 range from 0.05 mg/L to 0.5mg/L. Over the 2 weeks, the iron levels started to lower, with some outliers, perhaps due to the test kit's degree of error.

The results indicate that the iron levels are below than expected for a river or lake, which normally contains approx. 0.5-1 mg/L of iron. (FOSC org) [13] The low results could be inferred to iron being caused by storm water and Lily Pond being a natural lake. This shows that the initial level of iron was the healthiest, with the low results towards the end of the 2 weeks putting the pond ecosystem's at risk of aquatic deficiencies. Therefore it is concluded that a 20% duckweed density to be optimum as it reduced the iron the least, therefore ensuring the iron to be in a suitable range for living organisms.

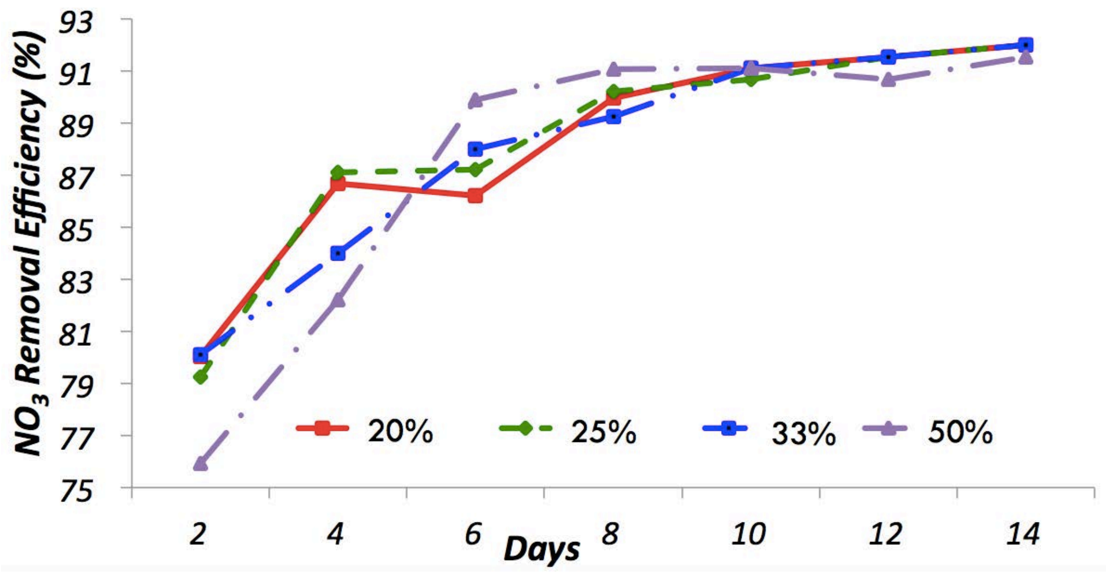



**Figure 4. Nitrate removal efficiency in different Lemna sp. ratios, initial: 2.25 mg/L**

Nitrate was the most important parameter measured, as it is the main cause of eutrophication. Nitrate is a form of nitrogen and is a vital component for healthy aquatic plant growth. Human activities resulting in pollution can lead to higher than usual levels of nitrate ions, which leads to the excessive growth of algae and consequently, eutrophication. (Wheatley River Improvement Group) [26]

Optimum nitrate levels in lakes range from 0.1-0.4 mg/L. Lily Pond's initial nitrate level was extremely high and unhealthy, at 2.25 mg/L, which explains Lily Pond's past history with eutrophication. However, by the end of the 2-week period, the nitrate levels had been filtered and decreased to results of approx. 0.18-0.19 mg/L.

Figure 5 shows that the efficiency over the course of 14 days was between a 75-80% removal rate, with the highest efficiency recorded being 92%. Figure 5 shows that duckweed needs a minimum of 6 days to have an extremely effective removal rate of around 75-80%. Figure 5 also shows that after 10 days, the nitrate removal rate had not increased, remaining stable, showing there is no further need for duckweed as a filtering scheme.

Research by N.C Museum of Natural Sciences stated that upon duckweed's death any nitrate contained in it would be released back into the ecosystem. (Charlotte Observer) [9] Therefore, it is suggested that after 10 days (where the nitrate removal rates reached maximum) excess duckweed should be removed and then act as fertiliser for terrestrial plants. This is so to prevent the return of nitrate to Lily Pond water. Also the N.C Museum research stated that after 4 weeks in a 10x9 inch pond with a 3-inch, nitrate was completely removed. This is also not ideal as nitrate is still essential for plant growth, which presents another purpose for the 10-day removal scheme.

With the nitrate results having a high removal efficiency of up to 92%, the results proves that duckweed has great potential as a natural and cost effective filtering source, especially as it's effectiveness is much stronger than chemical filtration, that has quite low filtering rates. A 20% covering ratio is determined to be optimum as it removes excess nitrate at 92% efficiency, only slightly differing from its larger counterparts while being easier to maintain. The 20% covering would also not damage pond appearance, allow the most light to pass and therefore not restrict the growth of other aquatic plants.

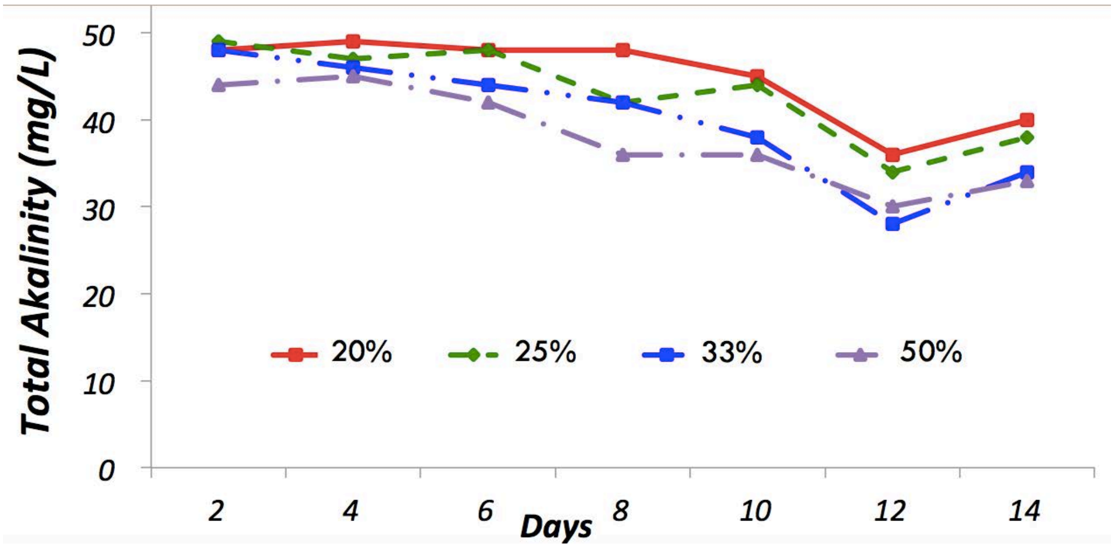



**Figure 5. Total alkalinity levels in different *Lemna sp.* ratios, initial: 54 mg/L**

Alkalinity protects or buffers against pH changes and has an acid neutralizing ability. The acceptable range for alkalinity in lakes is between 20-200 mg/L, and it is important to maintain a fairly high alkalinity level, to help buffer against harmful water acidity and pH changes. (Centre for Earth and Environmental Science) [7] All the alkalinity results are within the previously mentioned healthy limit. The alkalinity removal rate is fairly high, with the original of 54 mg/L reduced to 25-40 mg/L at the end of the 14 days. The alkalinity was not fully stripped, and showed that duckweed did not lower the alkalinity to unhealthy levels. All the rates are healthy, with the 20% duckweed ratio suggested as it reduced the alkalinity the least, ensuring the water's strong buffering capabilities.

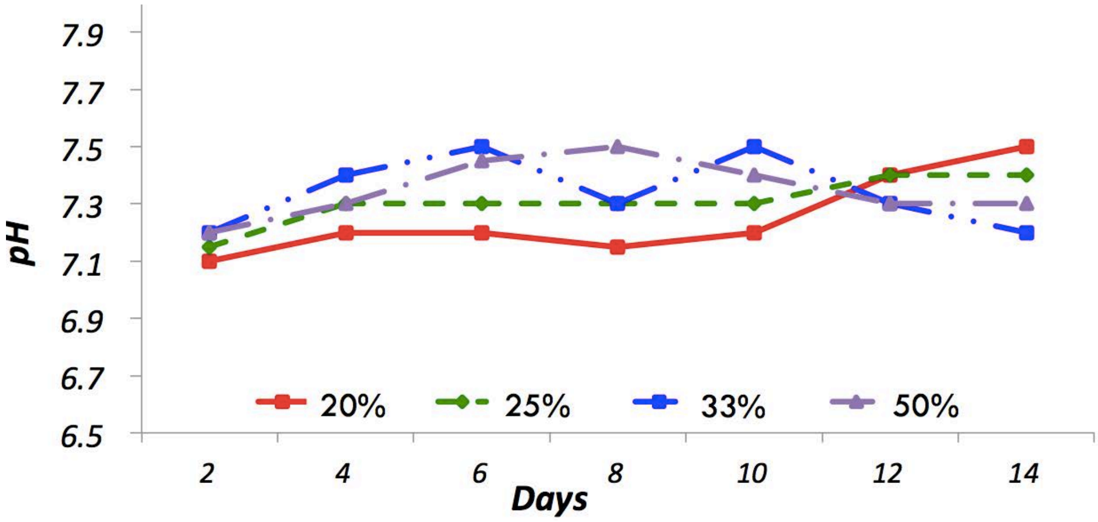



**Figure 6. Variation of pH in different *Lemna sp.* ratios, initial pH: 7.2pH**

pH is water acidity and affects the environment of a water source. (Fondriest) [12] Lily Pond initially was in an acceptable level of 7.2 pH and Figure 6 shows that the pH only varied very slightly to at most 7.7 pH.

The small variation shows that duckweed kept pH very stable, therefore not negatively affecting the pond ecosystem, unlike some other aquatic plants that may rapidly and negatively change the water acidity. Therefore, in the application of duckweed, Lily Pond would maintain it's current aquatic life. It is concluded that duckweed does not negatively change the pH levels and all densities would be suitable, with the 20% duckweed covering being proposed, as it requires the least upkeep.

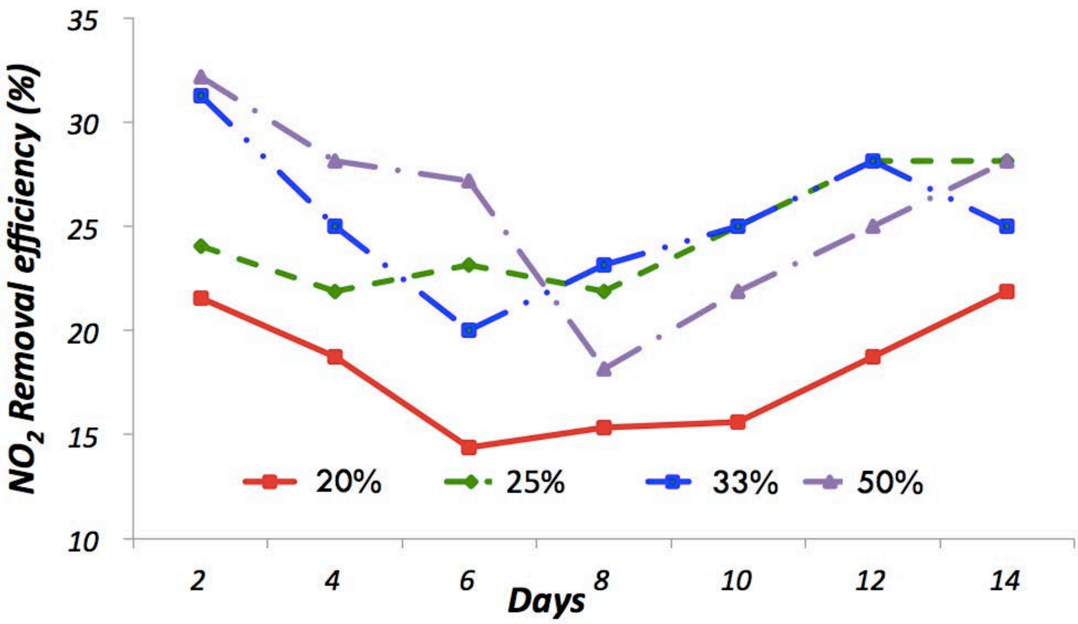



**Figure 7. Variation of nitrite in different *Lemna sp.* ratios, initial nitrite: 0.32 mg/L**

Nitrite can easily change into nitrate in water and is produced in the same way as nitrate. (Sydney Water) [25] Nitrite levels were all in an acceptable range, with the maximum efficiency of nitrite removal being 32%. The ending levels were 0.22-0.25 mg/L. These results are all considered to be acceptable for a lake environment, but duckweed does not remove nitrite as effectively as nitrate.

## ***Conclusions***

The main conclusion is that duckweed has demonstrated it's strong ability as a efficient and effective natural filter against eutrophication, especially in terms of nitrate control, while not having any noticeable negative affects on the pond's ecosystem or pH. This has proven that duckweed would be suitable as a natural form of eutrophication control.

Overall, the nutrient management rates for the different densities did not majorly differ. Most of the water qualities were within a healthy range, with the exception of iron and nitrate. Nitrate was extremely high and demonstrated the reason for Lily Pond's past history with eutrophication.

The hypothesis of 25% ratio being optimum is not supported. This is due to the 20% being proposed as the 20% had a better performance. This is due to its:

i) Extremely proficient removal of nitrate nutrients (of up to 92%)
ii) Removal of Nitrate ($NO_3$) better than the 50% ratio
iii) Not major variation between the 20% ratio and higher ratios
iv) Small density to ensure future growth and to not severely impact visual view of Lily Pond
v) Low cost and investment

## ***Practical applications***

Duckweed can be applied nationally or internationally, due to its high effectiveness and low investment cost. Duckweed is a viable environmental solution for authorities, especially in the 3rd world nations where eutrophication control remains a constant environmental issue and expensive treatments are not practical.

For practical applications of duckweed, a 10-day removal scheme is established, as mentioned in the discussion and conclusion. This would prevent large levels nitrate returning back into the pond ecosystem. Duckweed would then act as a fertiliser for terrestrial plants, due to its high nutrient content. Duckweed's high protein content can also be a food source for birds and aquatic animals. Therefore, duckweed would have multiple purposes, increasing its productivity and cost effectiveness.

## ***Future improvements***

In the future, it is recommended to conduct the results with more precise equipment, rather than test kits to ensure accuracy. It would also be beneficial to have larger scale tubs; to better mimic Lily Pond conditions and therefore, better predict the effects of duckweed on nutrient levels. Upcoming projects could also test out different duckweed densities, to determine whether a different lower or higher density would also be suitable for eutrophication control.

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